

CLAIMS

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

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1. A method of managing manufacturing logistics of end products comprising the steps of:
 maintaining an inventory of components, which components, termed "building blocks", are built to stock;
 configuring-to-order end products using said components; and
 replenishing said components from suppliers following a base-stock policy.

2. The method of managing manufacturing logistics of end products recited in claim 1, wherein the end products are personal computers (PCs) and the components are stock computer components.

3. The method of managing manufacturing logistics of end products recited in claim 1, wherein the base-stock levels are derived from a greedy algorithm which iteratively reduces inventory budget until a budget constraint is satisfied.

4. A computer implemented process of managing manufacturing logistics of configure-to-order end products comprising the steps of:
 a) initializing the process by setting $x_i := 0$ for each $i \in S$, setting $r_{mi} := P(X_{mi} > 0)$, setting $\beta_m := 0$ for each $m \in M$, and setting $\beta := 0$, where S is a set of components indexed by i , M is a set of end products indexed by m , x_i is the probability of no-stockout of a component of index i , r_{mi} is the probability

that a positive number of units of component i is used in the assembly of an end product indexed by m , β_m is the probability of stockout of an end product of index m , and β is the upper limit on the stockout probability over all end products;

b) setting the set of active components to $A := \{\}$;

c) considering each $i \in S$, followed by considering each end product m that uses component i in its bill-of-material;

d) setting $\beta_m := \beta_m + r_{mi} \Delta$, for all m such that $i \in S_m$ where Δ is a unit step size;

e) computing the difference $\delta_i := \max_m \{\beta_m\} - \beta$;

f) determining if $\delta_i \leq 0$, and if so, then adding component index i to the set of active components, $A := A + \{i\}$;

g) determining if the set of active components is non-empty, and if so, then setting $B := A$, otherwise setting $B := S$ where B is a set of component indexes;

h) finding $i^* := \arg \max_{i \in B} \{-c_i \sigma_j g'(x_j + \Delta/2)\}$, where $-g'(\bullet)$ follows the equation $-g'(x) = -\Phi(\bar{\Phi}^{-1}(x)) \cdot \frac{-1}{\phi(\bar{\Phi}^{-1}(x))} = \frac{1-x}{\phi(\bar{\Phi}^{-1}(x))}$, where $\Phi(\cdot)$ is the

probability distribution function of the standard normal variate, and $\phi(\cdot)$ is the probability density function of the standard normal variate;

i) setting $x_i^* := x_i^* + \Delta$ to update the probability of no-stockout of component i^* ;

j) computing $\beta := \max_{m \in M} \beta_m$, and checking whether inequality $\sum_{i \in S} c_i \sigma_j g(x_i) \leq B$, where B is the budget limit on the expected overall

inventory cost, is satisfied and if so, stop;

k) otherwise, updating β_m and for each $m \in M_{i^*}$, set $\beta_m := \beta_m + r_{mi} \Delta$, and

32 going to step b).

1 5. A system for managing manufacturing logistics of end products comprising:
 2 means for maintaining an inventory of components, which
 3 components, termed "building blocks", are built to stock;
 4 means for configuring-to-order end products using said components;
 5 and
 6 means for replenishing said components from suppliers following a
 7 base-stock policy.

1 6. The system for managing manufacturing logistics of end products recited in
 2 claim 5, wherein the end products are personal computers (PCs) and the
 3 components are stock computer components.

1 7. The system for managing manufacturing logistics of end products recited in
 2 claim 5, wherein the base-stock levels are derived from a greedy algorithm
 3 which is iteratively computed by a processing unit to reduce inventory budget
 4 until a budget constraint is satisfied.

1 8. A method that translates end-product demand forecast in an
 2 assemble-to-order (ATO) environment into a forecast for components, taking
 3 into account outbound leadtime comprising the steps of:
 4 defining the demand $D_m(t)$ of type m in period t , each unit of type m
 5 demand requiring a subset of components, denoted $S_m \subseteq S$, as

6
$$D_i(t) = \sum_{m \in M_i} D_m(t + L_m^{\text{out}}); \text{ and}$$

7 deriving mean and variance for demand $D_i(t)$ as

8
$$E[D_i(t)] = \sum_{m \in M_i} \sum_{\ell} E[D_m(t+\ell)] P[L_m^{\text{out}} = \ell], \text{ and}$$

9
$$\text{Var}[D_i(t)] = \sum_{m \in M_i} \sum_{\ell} E[D_m^2(t+\ell)] P[L_m^{\text{out}} = \ell] - \left(\sum_{m \in M_i} \left(\sum_{\ell} E[D_m(t+\ell)] P[L_m^{\text{out}} = \ell] \right) \right)^2, \text{ respectively.}$$

1 9. The method recited in claim 8, wherein the ATO environment is extended
2 to a configure-to-order (CTO) environment for stationary demand, taking into
3 account batch sizes comprising the steps of:

4 translating end-product demand into demand for each component i (per
5 period) as

6
$$D_i = \sum_{m \in M_i} \sum_{k=1}^{D_m} X_{mi}(k).$$

7 where $X_{mi}(k)$, for $k = 1, 2, \dots$, are independent, identically distributed (i.i.d.)
8 copies of X_{mi} ;

9 deriving marginal distributions, and then the mean and the variance of
10 X_{mi} as

11
$$E[D_i] = \sum_{m \in M_i} E[X_{mi}] E[D_m], \text{ and}$$

$$\begin{aligned} \text{Var}[D_i] &= \sum_{m \in M_i} \left(E[D_m] \text{Var}[X_{mi}] + \text{Var}[D_m] E^2[X_{mi}] \right) \\ &= \sum_{m \in M_i} \left(E^2[X_{mi}] E[D_m^2] + \text{Var}[X_{mi}] E[D_m] - E^2[X_{mi}] E^2[D_m] \right), \text{ respectively.} \end{aligned}$$

10. The method recited in claim 9, extended to non-stationary demand,
wherein the mean and the variance of X_{mi} are generalized as

$$E[D_i(t)] = \sum_{m \in M_i} E[X_{mi}] \sum_{\ell} E[D_m(t+\ell)] P[L_m^{\text{out}} = \ell], \text{ and}$$

$$\begin{aligned} \text{Var}[D_i(t)] &= \sum_{m \in M_i} E^2(X_{mi}) \sum_{\ell} E[D_m^2(t+\ell)] P[L_m^{\text{out}} = \ell] \\ &\quad + \sum_{m \in M_i} \text{Var}(X_{mi}) \sum_{\ell} E[D_m(t+\ell)] P[L_m^{\text{out}} = \ell] \\ &\quad - \sum_{m \in M_i} E^2(X_{mi}) \left(\sum_{\ell} E[D_m(t+\ell)] P[L_m^{\text{out}} = \ell] \right)^2, \text{ respectively.} \end{aligned}$$

11. The method recited in claim 9, further comprising the steps of:
defining $R_i(t)$ as a reorder point (or, base-stock level) in period t as

$$R_i(t) := \mu_i(t) + k_i(t) \sigma_i(t),$$

where $k_i(t)$ is the desired safety factor, while $\mu_i(t)$ and $\sigma_i(t)$ can be derived (via
queuing analysis as

6 $\mu_i(t) = \sum_{s=t}^{t+\ell_i^{\text{in}}-1} E[D_i(s)], \text{ and}$

7 $\sigma_i^2(t) = \sum_{s=t}^{t+\ell_i^{\text{in}}-1} \text{Var}[D_i(s)], \text{ respectively,}$

8 where $\ell_i^{\text{in}} := E[L_i^{\text{in}}]$ is expected in-bound leadtime; and

9 translating $R_i(t)$ into "days of supply" (DOS), where the $\mu_i(t)$ part of
10 $R_i(t)$ translates into periods of demand and the $k_i(t)\sigma_i(t)$ part of $R_i(t)$ is turned
11 into

12
$$\frac{k_i(t)\sigma_i(t)}{\frac{\mu_i(t)}{\ell_i^{\text{in}}}}$$

13 periods of demand so that $R_i(t)$ is expressed in terms of periods of DOS as

14
$$\text{DOS}_i(t) = \ell_i^{\text{in}} \left[1 + k_i(t) \frac{\sigma_i(t)}{\mu_i(t)} \right].$$

1 12. The method recited in claim 11, wherein demand is stationary in which for
2 each demand class m , $D_m(t)$ is invariant in distribution over time, so that the
3 mean and the variance of demand per period for each component i reduce to

4 $\mu_i = \ell_i^{\text{in}} E[D_i]$, and $\sigma_i^2 = \ell_i^{\text{in}} \text{Var}[D_i]$, respectively, and

5 $R_i = \ell_i^{\text{in}} E[D_i] + k_i \sqrt{\ell_i^{\text{in}}} \text{sd}[D_i]$, and hence,

6
$$\text{DOS}_i = \frac{R_i}{E[D_i]} = \ell_i^{\text{in}} + k_i \theta_i \sqrt{\ell_i^{\text{in}}} = \ell_i^{\text{in}} \left[1 + k_i \frac{\theta_i}{\sqrt{\ell_i^{\text{in}}}} \right],$$

7 where $\theta_i := \text{sd}[D_i]/E[D_i]$ is the coefficient of variation of the demand *per*
 8 *period* for component i , and hence $\theta_i / \sqrt{\ell_i^{\text{in}}}$ is the coefficient of variation of
 9 the demand over the leadtime ℓ_i^{in} .

1 13. A method that relates service requirements to base-stock levels of the
 2 components in an assemble-to-order (ATO) environment comprising the steps
 3 of:

4 defining each order of type m as requiring exactly one unit of
 5 component $i \in S_m$, α as a required service level, referred to as off-shelf
 6 availability of all the components required to configure a unit of type m
 7 product, for any m , and E_i as an event that component i is out of stock;
 8 determining a probability P for each end product $m \in M$,

9
$$P[\cup_{i \in S_m} E_i] \leq 1 - \alpha, \text{ and}$$

10
$$P[\cup_{i \in S_m} E_i] = \sum_i P(E_i) + \sum_{i < j} P(E_i \cap E_j) + \sum_{i < j < k} P(E_i \cap E_j \cap E_k) - \dots, \text{ and}$$

11

$$P[\cup_{i \in S_m}] \approx \sum_{i \in S_m} P(E_i) = \sum_{i \in S_m} \bar{\Phi}(k_i) \leq 1 - \alpha.$$

1

14. The method recited in 13, wherein the method is extended to a configure-to-order (CTO) environment taking into account batch sizes, further comprising the steps of:

4

defining $A \subseteq S_m$ as a certain configuration, which occurs in a demand stream with probability $P(A)$;

5

6

weighting a no-stockout probability, $\prod_{i \in A} \bar{\Phi}(k_i)$, by $P(A)$;

7

changing the service requirement to

8

$$\begin{aligned} \alpha &\leq \sum_{A \subseteq S_m} P(A) \prod_{i \in A} \bar{\Phi}(k_i) \\ &\approx \sum_{A \subseteq S_m} P(A) [1 - \sum_{i \in A} \bar{\Phi}(k_i)] \\ &= 1 - \sum_{A \subseteq S_m} P(A) \sum_{i \in A} \bar{\Phi}(k_i) \\ &= 1 - \sum_{i \in S_m} \left(\sum_{i \in A} P(A) \right) \bar{\Phi}(k_i); \text{ and} \end{aligned}$$

9

extending the CTO environment the service requirement to

10

$$\sum_{i \in S_m} r_{mi} \bar{\Phi}(k_i) \leq 1 - \alpha.$$

1

15. A method that translates service requirements in terms of leadtimes

2

into requirements for the off-shelf availability of the components comprising

3

the steps of:

relating an off-shelf availability requirement to standard customer service requirements expressed in terms of leadtimes, W_m , where a required service level of type m demand is

$$P[W_m \leq w_m] \geq \alpha, \quad m \in M,$$

where w_m 's are given data and P is probability;

when there is no stockout at any store $i \in S_m$, denoting the associated probability as $\pi_{0m}(t)$, a delay being L_i^{out} , the out-bound leadtime;

when there is a stockout at one or several stores in the subset $s \subseteq S_m$, denoting the associated probability as $\pi_{sm}(t)$, so that the delay becomes $L_i^{\text{out}} + \tau_s$, where τ_s is the additional delay before the missing components in s become available;

$$\text{determining } P[W_m \leq w_m] = \pi_{0m}(t)P[L_m^{\text{out}} \leq w_m] + \sum_{s \in S_m} \pi_{sm}(t)P[L_m^{\text{out}} + \tau_s \leq w_m];$$

and

assuming that

$$L_m^{\text{out}} \leq w_m \quad \text{and} \quad L_m^{\text{out}} + \tau_s > w_m$$

both hold *almost surely*, so that when the (nominal) outbound leadtime is nearly deterministic and shorter than what customers require, whereas the replenish leadtime for any component is substantially longer.